Forest Floor in the Piedmont Region of South Carolina[1]

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ABSTRACT

The annual litter fall, weight of forest floor, and organic matter incorporation in the surface foot of mineral soil are reported for three pine, three pine-hardwood, and three hardwood stands in the South Carolina Piedmont.

The litter fall for the stands averaged 4,400 pounds per acre, of which 3,500 pounds was leaf material. The weight of the forest floor was greatest in the pine stands and least in the hardwoods. The forest floor weight, expressed on a volatile matter basis, ranged from 6,160 pounds per acre in an old hardwood stand to 16,430 pounds in a 40-year-old shortleaf pine stand. The organic matter content in the surface foot of mineral soil ranged from 83,550 pounds per acre in the old hardwood stand to 25,780 pounds in a young loblolly pine plantation. The weight of the forest floor and organic matter in the mineral soil show that decomposition is more rapid beneath hardwood stands.

The forest floors are classified as to humus type and the discussion presented shows some practical application of the information to forest management work.

The study reported here was made to learn more about the litter contribution to the soil from different forest stands in the Piedmont region of South Carolina, and the practical application of this information to forest management. Although such studies have been conducted elsewhere, no information on the subject is available for this area.

Plots were established in three pine, three pine-hardwood, and three hardwood stands in Union County, S. C. Data are presented on the addition of litter to the forest floor, the weight of material making up this floor, and the organic matter content of the surface foot of mineral soil.

The practical implications of different humus types, known to the Europeans for many years, have only recently been utilized in this country. Interest in the subject has been stimulated as general knowledge of forest soils increases. Information on the organic layers of forest soils has been used in classifying sites with respect to growth, seedbed characteristics, and effect of fire on the soil, and in watershed studies concerned with water movement and storage.

Description of Study Area

A description of the vegetation in these stands has been reported (7). Stand 1 consists of a mixture of loblolly and shortleaf pines about 25 years old. Stand 2 is 40-year-old shortleaf pine and stand 3 is a 12-year-old loblolly pine plantation. The mixed stands have trees up to 50 years old and consist of shortleaf pine and a variety of upland hardwoods. Stand 7 is made up predominantly of yellow-poplar with trees up to 45 years. Stand 8 has mostly hickory which is 150 years old and stand 9 is predominantly oak with trees up to 50 years. In stand 9 60% of the leaf fall is from oak species whereas in the other two hardwood stands it is but 15%. The basal area in all stands averages around 91 square feet per acre. The only striking deviations are stand 2 with 126 square feet and stand 9 with 62 square feet.

The humus types, along with the depth and texture of the A horizons, are listed in table 1. Most of the original surface horizon has been washed away and the present A horizon is a sandy plowed layer developed by cultivation. There is practically no transition zone between the A horizon and the underlying clay soil. Nomenclature for types is from the published report of the committee on forest humus classification of Division V-A, Forest Soils, of the Soil Science Society of America (5). Two of the pine stands have an imperfect mor with no H-layer and no visible incorporation of organic matter in the mineral soil. This is the type of floor found beneath all young pine stands coming in on abandoned fields, regardless of the surface soil texture. One pine stand has a thin mor in which a shallow H-layer has developed but no incorporation of organic matter is evident in the mineral soil. One of the mixed stands has a sand mull humus type in which no H-layer is present and the sandy mineral soil is mixed with the organic matter as single grains. The other two mixed stands have thin duff mulls, with thin H-layers and shallow A_1 horizons. The A_1 horizon is the upper part of the sandy surface soil which is darkened by organic matter. Two of the hardwood stands have a deep coarse mull, with an A_1 horizon from 2 to 4 inches in thickness. The other hardwood stand has a thin duff mull similar to those found under the mixed stands.

The soils represented in this study are Cecil, Cataula and Vance, from acid crystalline rocks; Lloyd from basic crystalline rocks; and Helena from mixed acidic and basic rocks. The surface soils are sandy loams and range from 2 to 12 inches in thickness.

Litter Fall

Based on two years of data collected in the areas described above, the total litter fall for Piedmont stands averages 4,400 pounds per acre per year, of which 3,500 pounds is leaf material and the remainder twigs, bark, and fruit. These values hold, regardless of species, over the range of stand densities sampled.

In the pine stands, the annual leaf fall contains 18 pounds of calcium and 13 pounds of nitrogen per acre. The leaf fall of the hardwood stands contains 85 pounds of calcium and 26 pounds of nitrogen. The average leaf fall of the mixed stands has 43 pounds of calcium and 23 pounds of nitrogen. The calcium was precipitated as calcium oxalate (4) and nitrogen determined by Kjeldahl method (1).

Forest Floor

The weight of the forest floor, which is a reflection of the decomposition rate, is least for hardwoods and greatest for pine stands (table 2). The pine plantation is an exception to this because it is too young for equilibrium conditions to develop. Although the weight of the floor is about the same in the three hardwood stands, in stand 9 there are L, F, and H-layers present, while in the other two, there is only an L-layer. The difference in decomposition in the hardwood stands is probably due to the greater quantity of oak leaves in the litter beneath stand 9.

The forest floor weight was determined by lifting twelve 1-square-foot samples in each stand. A sharp-edged metal frame was driven into the ground, the material picked up by layers, oven-dried, and weighed. Sampling was done in the autumn just before the hardwood leaf fall began, when the weight of the floor was minimum.

It is difficult to san [illegible] s without picking up some mineral soil. This mineral matter can cause wide discrepancies even in closely paired samples. In order to remove this source of variation, the weight of mineral soil is eliminated by expressing the forest floor weights on a volatile-matter basis. The weight of the volatilized matter, determined by placing samples in a muffle furnace for 4 hours at 450°C., is considered

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Table 1.—Humus type, soil series, and thickness of A-horizon in nine Piedmont stands.

Stand Number	Vegetation	Humus type	Soil series	Thickness of A-horizon in inches
1	Pine	Imperfect mor	Cecil sandy clay	4
2	Pine	Thin mor	Cataula sandy loam	4
3	Pine	Imperfect mor	Cataula sandy loam	5
4	Pine-hardwoods	Sand mull	Helena loamy sand	12
5	Pine-hardwoods	Thin duff mull	Vance sandy loam	5
6	Pine-hardwoods	Thin duff mull	Cataula sandy loam	2
7	Hardwoods	Deep coarse mull	Vance sandy loam	6
8	Hardwoods	Deep coarse mull	Lloyd sandy loam	7
9	Hardwoods	Thin duff mull	Helena loamy sand	10

to be the quantity of forest floor present. The volatile matter value is not an exact measure of organic material, as some elements in the organic matter are left in the ash, and some elements and tightly held water in the soil are removed by the heat. These latter factors are minor compared to variation caused by the mineral soil in the sample.

The nitrogen in the floor depends on the number of layers present and the species on the site (table 2). For example, the forest floor of stand 2 has L, F, and H layers, weighs about 16,000 pounds per acre, and contains 165 pounds of nitrogen. The floor in stand 7 has only an L-layer weighing 8,700 pounds and contains 145 pounds of nitrogen per acre. The quantity of nitrogen is greatest in the lower layers of the forest floor. Weights of all forest floor samples used in nitrogen analyses were corrected for the mineral soil present.

Soil Organic Matter and Nitrogen

The organic matter content of the surface foot of mineral soil is greatest in hardwood stands and least in the pine stands (table 4). The hardwood stand composed mostly of oaks is an exception to this in that it has about the same amount of organic matter as beneath the pines. This is probably due to the decomposition rate of the oak leaf material and the fact that the mineral soil is very sandy and thus subject to rapid oxidation and leaching.

Organic matter was determined on samples from 12 pits in each stand by a wet combustion method (2). Adjacent to each pit, samples for bulk density were collected so that the organic matter values could be expressed on a weight basis. Bulk densities were determined on undisturbed samples collected in an apparatus similar to that described by Lutz (6). These bulk densities (table 3) are greatest beneath the pine stands in the surface 6 inches of soil. This shows that the soil beneath these stands is more compact and has less pore space than the others.

Table 2.—Weight in pounds per acre of forest floor in some Piedmont forest stands. Values are expressed on oven-dry weight and volatile matter weight basis.

Stand* Number	Layer	Oven-dry material	Volatile matter	Volatile matter	Nitrogen
		pounds per acre	%	pounds per acre	pounds per acre
1	L	4,110	96	3,950	19
	F	12,600	80	10,080	107
	Total	16,710		14,030	126
2	L	4,260	95	4,050	24
	F	7,260	88	6,390	61
	H	11,750	51	5,990	80
	Total	23,270		16,430	165
3	L	4,640	96	4,450	22
	F	8,290	77	6,380	59
	Total	12,930		10,830	81
4	L	4,870	87	4,240	45
	F	8,360	63	5,270	77
	Total	13,230		9,510	122
5	L	3,530	89	3,140	39
	F	4,460	80	3,570	56
	H	9,040	56	5,060	89
	Total	17,030		11,770	184
6	L	2,980	91	2,710	30
	F	5,140	79	4,060	59
	H	9,930	45	4,470	67
	Total	18,050		11,240	156
7	L	11,940	73	8,720	145
	Total	11,940		8,720	145
8	L	8,000	77	6,160	85
	Total	8,000		6,160	85
9	L	2,780	91	2,530	34
	F	3,780	74	2,800	48
	H	6,470	43	2,780	52
	Total	13,030		8,110	134

*Stands 1 to 3, pine; stands 4 to 6, pine-hardwood; stands 7 to 9, hardwood.

Table 3.—Bulk density of surface foot of soil beneath nine Piedmont forest stands.

Depth in inches	Pine stands			Pine-hardwood stands			Hardwood stands		
	1	2	3	4	5	6	7	8	9
0–2	1.21	1.35	1.40	0.94	0.99	1.08	0.98	0.82	0.99
2–4	1.39	1.50	1.47	1.09	1.20	1.23	1.08	1.16	1.23
4–6	1.37	1.54	1.45	1.17	1.24	1.26	1.28	1.23	1.26
6–8	1.38	1.56	1.36	1.31	1.31	1.24	1.31	1.31	1.37
8–10	1.36	1.41	1.40	1.34	1.43	1.24	1.27	1.38	1.40
10–12	1.34	1.39	1.32	1.45	1.40	1.25	1.36	1.37	1.38

Table 4.—Organic matter content of mineral soil to a depth of 12 inches. Expressed in percent oven-dry weight and pounds per acre.

Stand*	Soil depth in inches												
	0–2	2–4	4–6	6–8	8–10	10–12	0–2	2–4	4–6	6–8	8–10	10–12	0–12
	% oven-dry weight						pounds per acre						
1	1.48	1.03	0.97	0.93	0.88	0.76	8,110	6,490	6,080	5,880	5,480	4,610	36,650
2	1.15	1.01	0.90	0.73	0.64	0.55	7,030	6,930	6,280	5,090	4,090	3,460	32,880
3	0.93	0.73	0.66	0.62	0.54	0.47	6,530	4,860	4,340	3,820	3,420	2,810	25,780
4	2.85	1.92	1.17	0.83	0.50	0.50	12,140	9,480	6,200	4,930	3,040	3,280	39,070
5	4.11	1.79	1.10	0.80	0.50	0.52	18,430	9,730	6,240	4,750	3,240	3,300	45,690
6	5.71	2.49	1.92	1.58	1.36	1.06	27,940	13,880	10,960	8,880	7,640	6,000	75,300
7	6.61	3.67	2.34	1.29	0.97	0.86	29,350	17,960	13,570	7,120	5,580	5,300	78,880
8	8.04	3.59	2.21	1.52	1.25	0.91	29,870	18,870	12,320	9,020	7,820	5,650	83,550
9	3.38	1.03	0.70	0.54	0.51	0.45	15,160	5,740	4,000	3,350	3,240	2,800	34,290

*Stands 1 to 3, pine; stands 4 to 6, pine-hardwood; stands 7 to 9, hardwood.

Table 5.—Nitrogen content of mineral soil to a depth of 12 inches. Expressed in percent oven-dry weight and pounds per acre.

Stand*	Soil depth in inches												
	0–2	2–4	4–6	6–8	8–10	10–12	0–2	2–4	4–6	6–8	8–10	10–12	0–12
	% oven-dry weight						Pounds per acre						
1	0.034	0.024	0.022	0.021	0.020	0.018	186	151	136	130	123	109	835
2	0.013	0.013	0.020	0.015	0.012	0.017	80	88	140	106	77	107	598
3	0.023	0.019	0.016	0.022	0.019	0.019	146	127	105	136	121	114	749
4	0.107	0.064	0.051	0.030	0.024	0.028	456	316	270	178	146	184	1,550
5	0.131	0.056	0.040	0.020	0.014	0.014	587	304	225	119	91	89	1,415
6	0.130	0.056	0.044	0.037	0.033	0.028	636	312	251	208	185	159	1,751
7	0.238	0.132	0.084	0.043	0.035	0.031	1,056	645	487	255	201	191	2,835
8	0.295	0.134	0.084	0.051	0.040	0.033	1,096	704	468	303	250	205	3,026
9	0.126	0.034	0.030	0.017	0.016	0.018	565	189	171	106	102	113	1,246

*Stands 1 to 3, pine; stands 4 to 6, pine-hardwood; stands 7 to 9, hardwood.

Since most of the nitrogen in forest soil (table 5) is bound up in organic tissue, it has the same relationship between the various stands as the organic matter, that is, least in pine stands and greatest in hardwoods. From 150 analyses of soil nitrogen (1) and organic matter, a good correlation was established. The regression equation derived, significant at the 1% level, is $Y = 0.0049 + 0.0281X$, where Y is percentage of total nitrogen, and X is percentage of organic matter. The values listed in the table are the direct determinations made for soil nitrogen and were not calculated with the equation.

Discussion

All of the nine Piedmont forest stands studied have about the same amount of litter added to the forest floor each year. However, since the foliage among the different species varies in the amount of calcium and nitrogen it contains, the quantities of these elements added to the forest floor under the different stands varies considerably.

The weight of the forest floor varies among the stands because some leaf tissue decomposes more rapidly than others. The pine litter, resistant to decay and only slightly attacked by insects, accumulates on the soil surface. The type of biological activity under pure pine does not result in incorporation of organic material with the mineral soil. The relatively small quantity of material remaining as forest floor under the hardwood stands having a large percentage of hickory and yellow-poplar shows that such litter material is subject to rapid decay. In these stands, rapid decomposition and vigorous biological activity result in the rapid incorporation of organic matter into the mineral soil. Other hardwood stands which are predominantly oak, such as number 9, often produce an H-layer. This has been previously reported by Coile (3) for a stand consisting of white oak, black oak and red oak on the Piedmont of North Carolina. In mixed pine-hardwood stands the hardwood species apparently decompose fairly rapidly to form an A_1 horizon, while the pine litter, slower to decompose, form a thin H-layer. Of course, if the hardwoods in such stands are principally oaks, then this litter might also contribute to the H-layer.

The relative rates and ease of decomposition of the surface layers is substantiated by measurements of the organic matter content of the mineral soil. The quantity of organic matter in the surface foot of mineral soil is appreciably less under the pine stands than under the hardwoods, while the pine-hardwood stands fall between the two extremes. Since nitrogen in the soil is closely correlated with organic matter content, the same relative relationship holds for nitrogen as for organic matter. The age of the vegetation and past land use do effect the organic matter content in the mineral soil to some extent. However, stands 2, 5 and 7, are about the same age and have the same surface soil texture, but table 4 shows that in the surface foot there are large differences associated with differences in stand composition.

Even the limited range of data represented by these

stands shows the value of separating sites on a basis of forest floor and A_1 horizon characteristics. Such a classification may be useful in predicting the severity of a fire. Under a given set of burning conditions, the weight and type of surface organic layers will help determine the intensity of the fire. A heavy forest floor will contribute more fuel to the fire, and loose pine needles will be more easily consumed than a compact layer of hardwood leaves.

The effect of fire on the soil is going to be governed by the type of forest floor present. In the imperfect mor type, almost any fire will consume all of the forest floor and expose the mineral soil to raindrop impact and frost action. In other mor types, the H-layer often resists combustion and furnishes a protective layer to the soil. However, certain fires may consume the H-layer and bare the mineral soil. In the mors, there is little aggregation and organic matter in the mineral soil; and when this soil is exposed, it is easily sealed off by rainfall. Removal of the forest floor is least serious in the mull types because the properties of the mineral soil are such that they can absorb and transmit water even when exposed. The desirable properties in the mulls are due largely to the presence of organic matter and soil fauna in the mineral soil. Earthworms and millipedes, which are very active in the mull types, are seldom found in the mors. The duff mull types have surface organic layers like the mors but also some incorporation of organic matter in the mineral soil. As a result of the incorporation, the duff mulls are probably less susceptible to fire damage than the mors.

Less of the nutrient capital is destroyed by fire on sites with organic matter in the mineral soil. When fire consumes the litter layers, the elements are either volatilized or left in the ash in which form they are susceptible to leaching and washing away. If they are lost to the site after a fire, the effect on the fertility level will be most pronounced where the reserve of such material in the mineral soil is least.

The type of humus layer present is also useful in describing the hydrologic characteristics of forest soil (8). The mull types, with their greater porosity, can store more water and transmit it more rapidly than the mors. As seen in table 3, the bulk density is less, and thus the pore space greater, in the duff mull and mull types. When fully saturated, the surface 6 inches of the mor types will hold 2.77 inches of water, the duff-mull types 3.36 inches, and the mulls 3.54 inches.

Practically all of the forests of the Piedmont are growing on abandoned agricultural land. When pines come in on such areas, an imperfect mor is formed by the litter and lasts until the stand is 20 to 30 years old. About this time a thin H-layer develops which becomes somewhat thicker as the stand ages. Hardwoods then begin to invade the stand and form an understory. On some sites the hardwoods remain as an understory, while in others they grow into the upper canopy. In either event, their effect on the forest floor is pronounced. As the hardwood litter is added to the forest floor, an A_1 horizon begins to develop and becomes progressively thicker as the stand ages. On most areas when the pine is removed, hardwoods take over the site. The thickness of the H and A_1 horizons in these hardwood stands and in the pine-hardwood mixtures will depend on the decomposition rate of the material forming the forest floor. Even though climatic conditions of the Piedmont are conducive to rapid decomposition, it is apparent that organic matter can be built up and maintained in the soil. When there is a continued supply of organic matter added to the surface, and the material is of such nature that it will be attacked by soil fauna, it will be incorporated with the mineral soil.

The organic layers of forest soils are a valuable diagnostic tool for timber and watershed management. They are amenable to change by modifications of the vegetation on the site. Where conditions are such that the forest soil should be improved, steps should be taken to manage the stands so that some readily decomposable material will be in the litter.

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